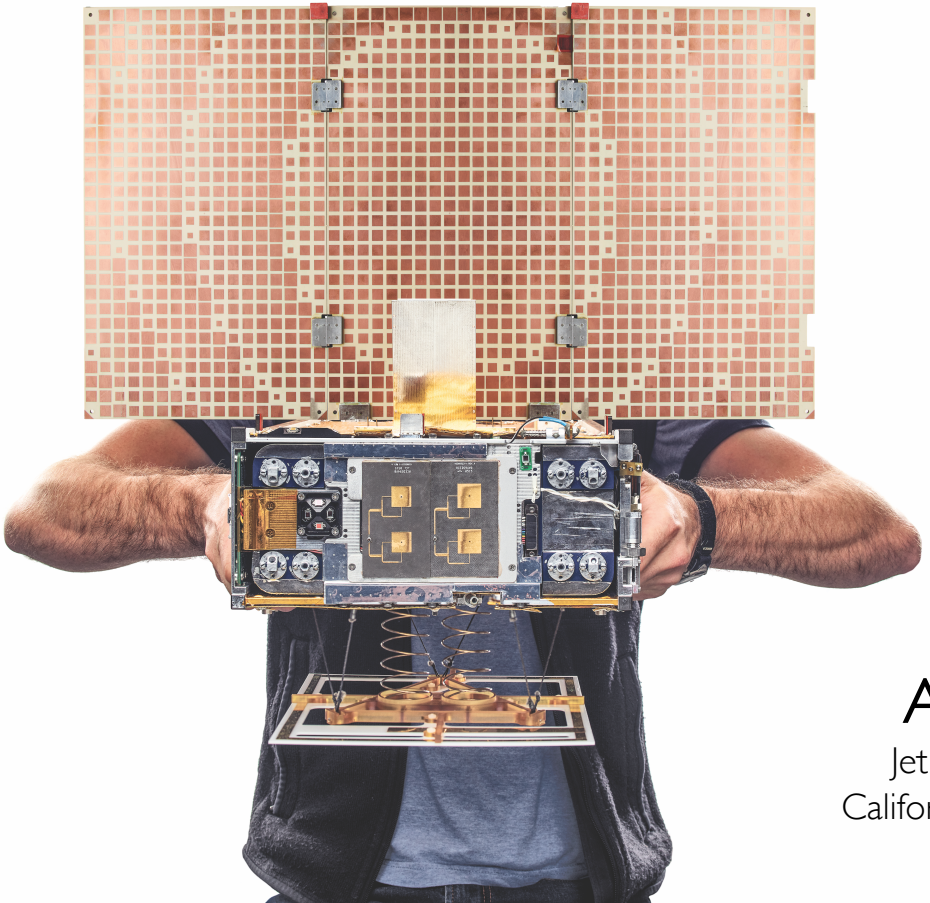
MarCO

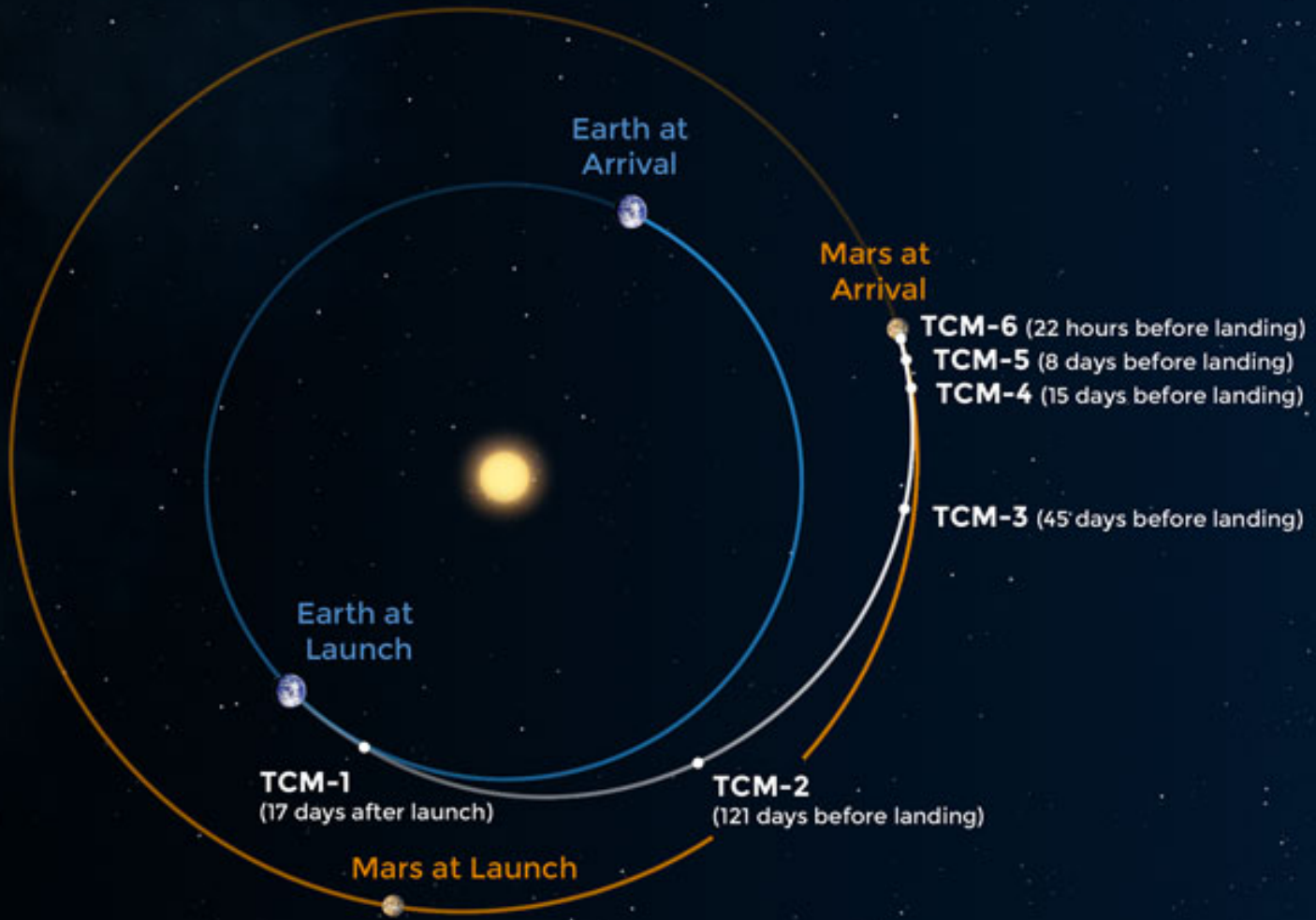
Mars Cube One

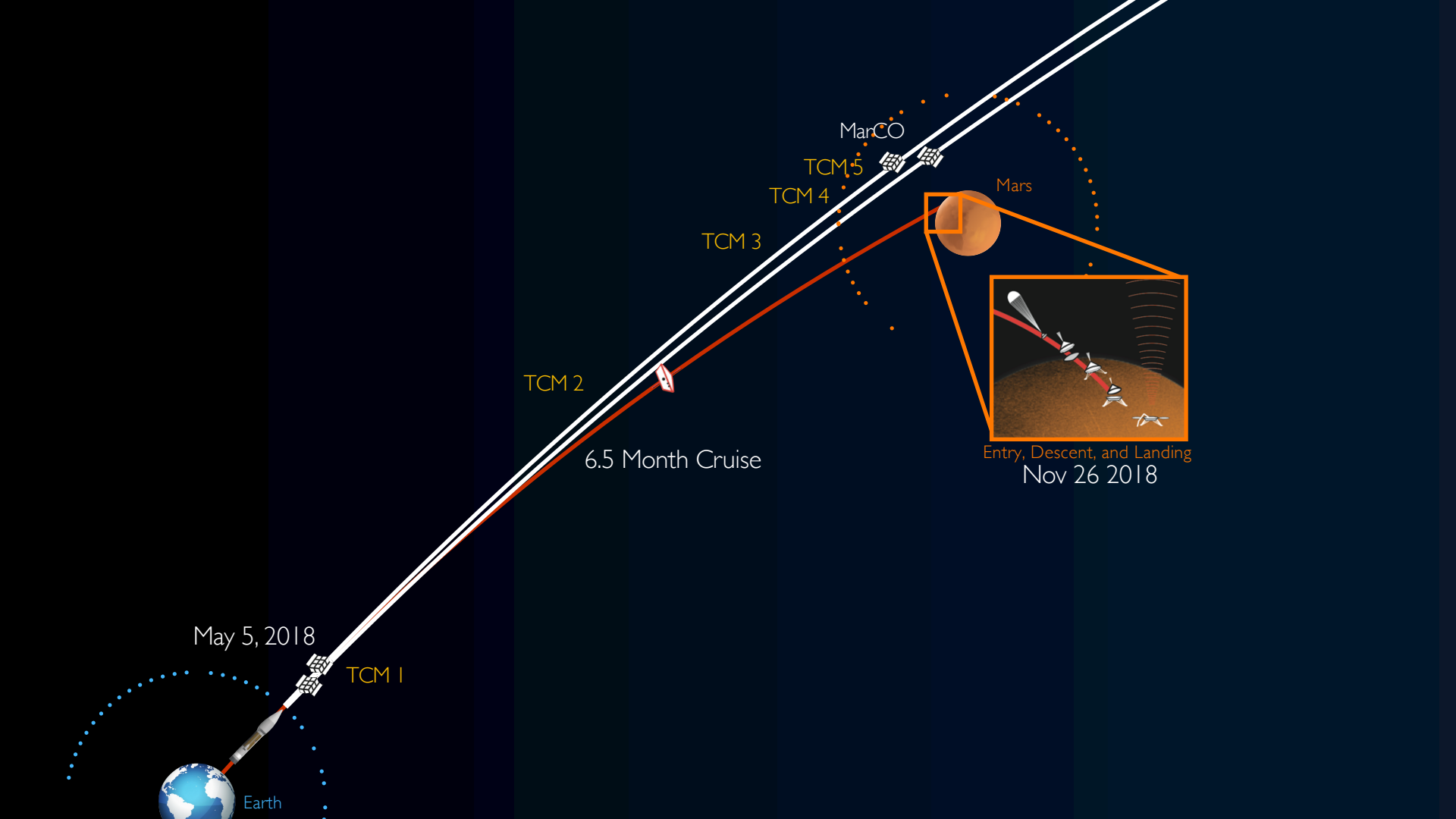


Andrew Klesh

Jet Propulsion Laboratory

California Institute of Technology

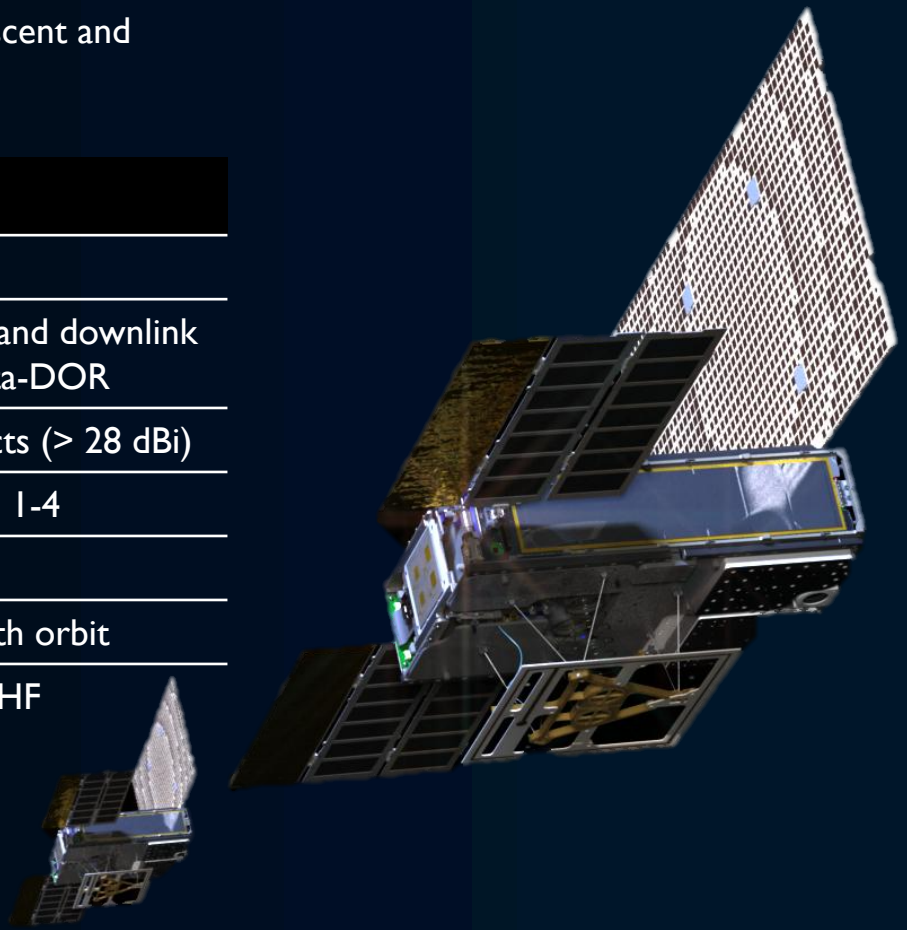

Earth at Arrival
Mars at Arrival
TCM-6 (22 hours before landing)
TCM-5 (8 days before landing)
TCM-4 (15 days before landing)
TCM-3 (45 days before landing)
Earth at Launch
TCM-1
(17 days after launch)
TCM-2
(121 days before landing)
Mars at Launch


MarCO
TCM 5
TCM 4
TCM 3
TCM 2
Mars
6.5 Month Cruise
Entry, Descent, and Landing
Nov 26 2018
May 5, 2018
TCM 1
Earth

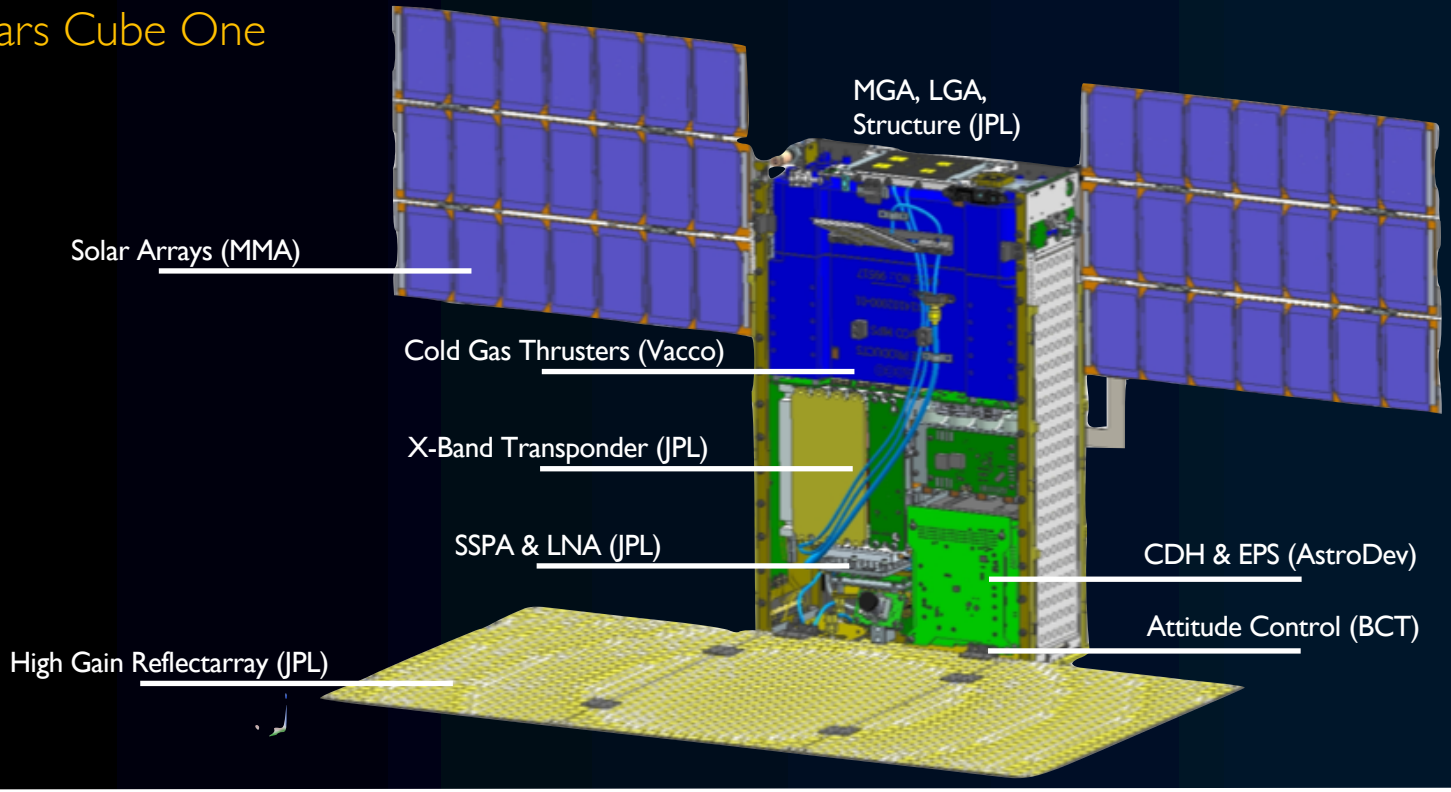
Mission Objective

- Provide an 8kbps real-time relay for InSight's Entry, Descent and Landing at Mars

Technology	Tech Objectives / Results
Threshold	
Miniaturized deep space radio (IRIS)	Successful uplink (62.5 – 1k) and downlink (62.5 – 16k) + ranging + Delta-DOR
Flat Panel Antenna	Measured gain matches predicts (> 28 dBi)
TCMs on a Cubesat	Completed execution of TCM 1-4
Baseline	
CubeSat in deep space	Viable operations beyond Earth orbit
Bent-Pipe Relay	Inflight demo with Stanford UHF bent-pipe + Insight EDL



MarCO: Mars Cube One

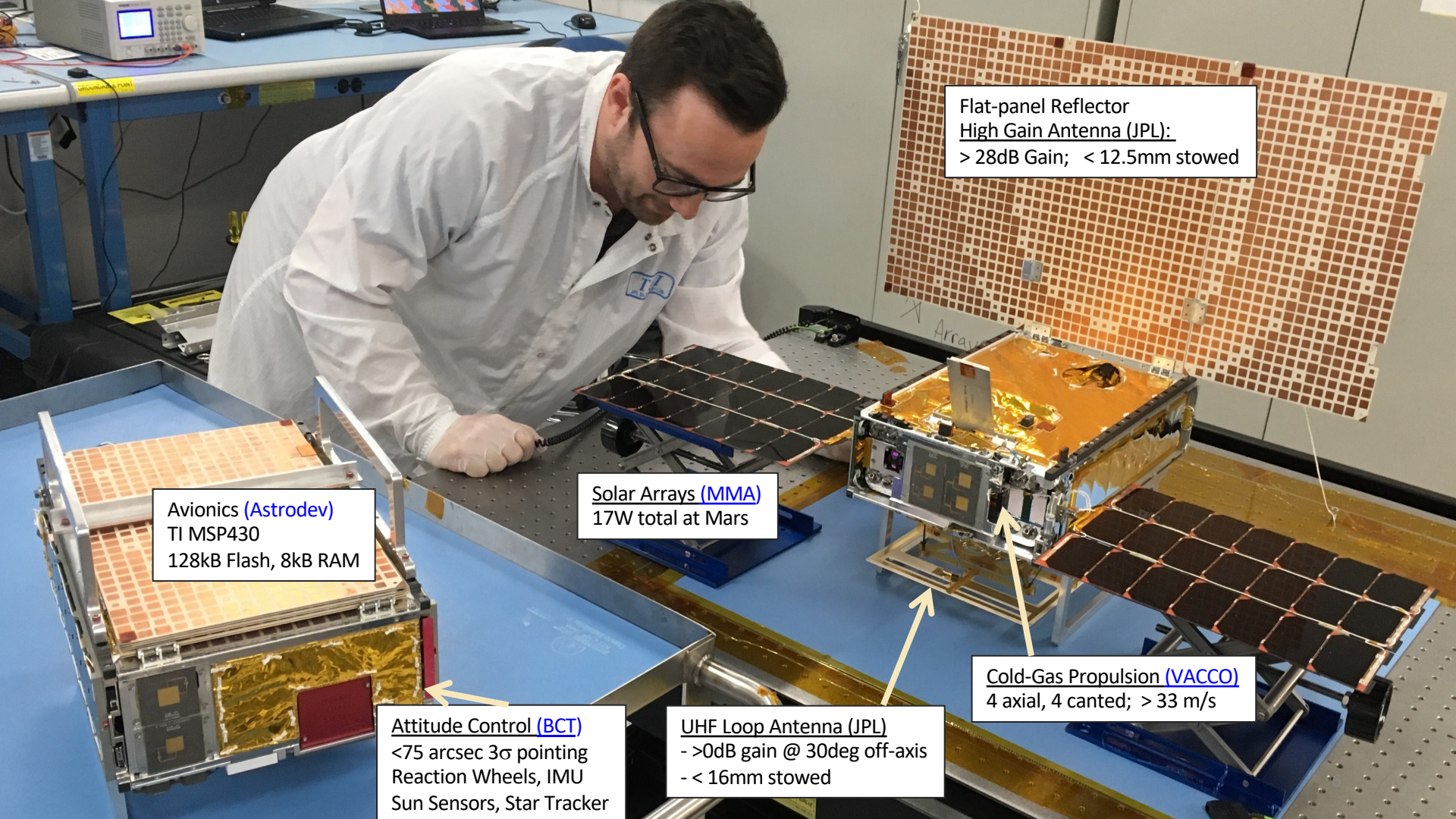


MarCO Overview:
Volume: 2 x 6U (12x24x36cm)
Mass: 14.0 kg
Power Generation:
Earth: 35 W / Mars: 17W
Data Rates: 62-8,000 bps
Delta-V: >40 m/s

Software:
FSW: protos (JPL)
GSW: AMPCS (NASA/JPL)

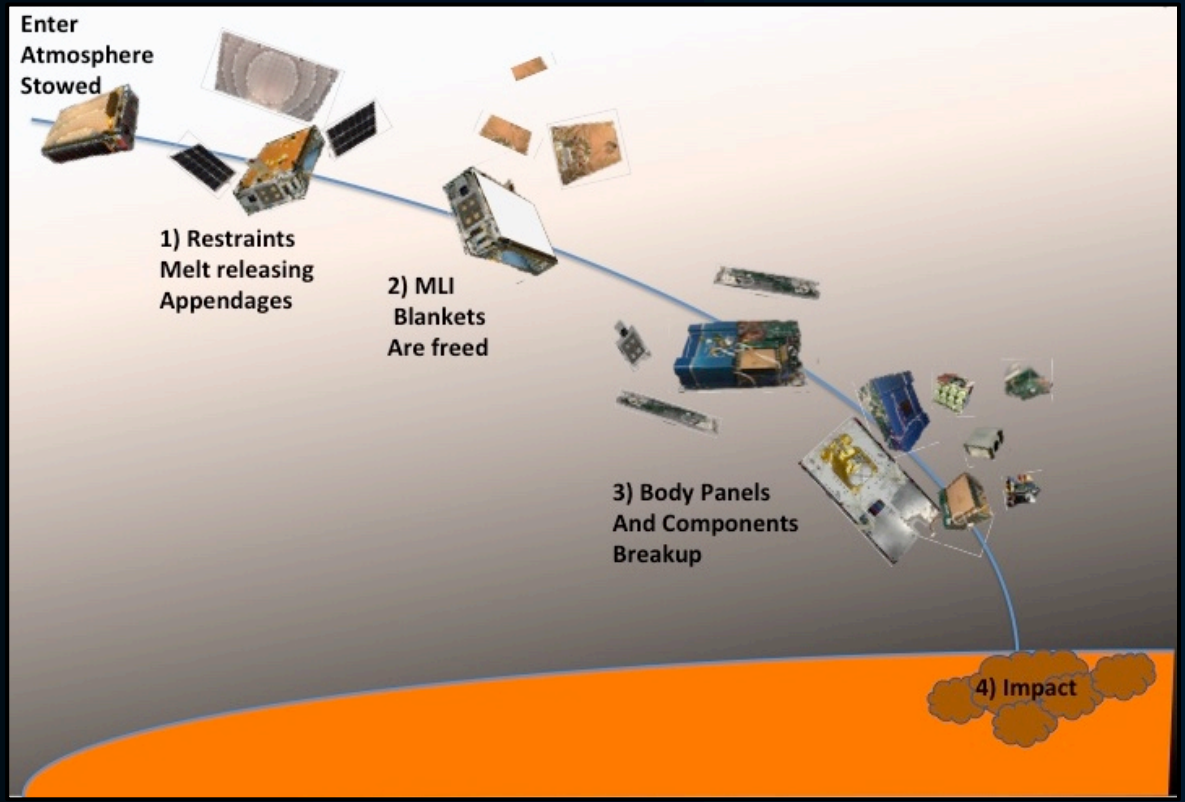
I&T:
In-house S/C I&T, testing,
Tyvak NLAS/Launch Integration

Operations:
Primary: DSN 34m
EDL: Madrid 70m

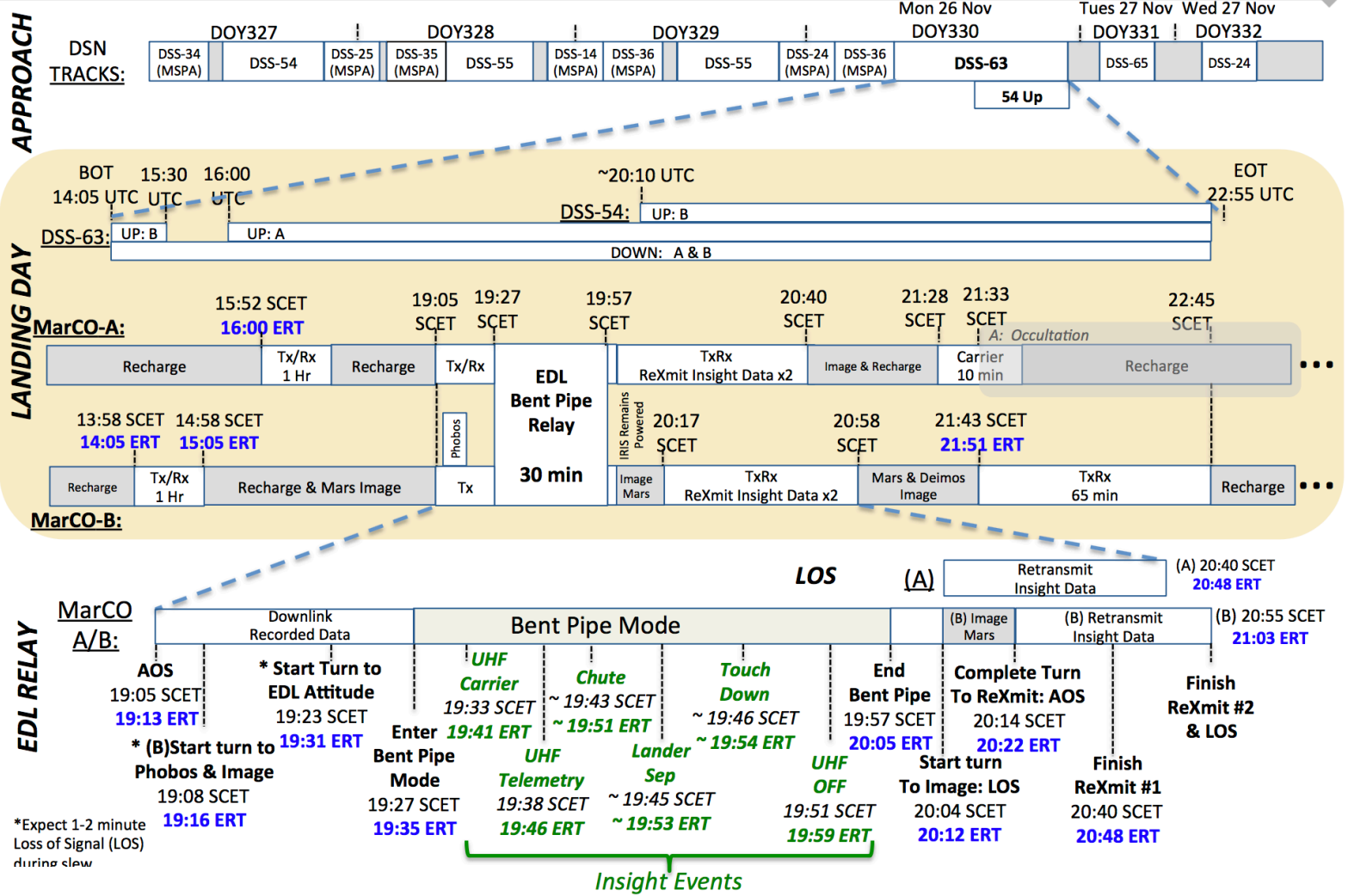

Flat-panel Reflector
High Gain Antenna (JPL):
> 28dB Gain; < 12.5mm stowed
Avionics (Astrodev)
TI MSP430
128kB Flash, 8kB RAM
Solar Arrays (MMA)
17W total at Mars
Cold-Gas Propulsion (VACCO)
4 axial, 4 canted; > 33 m/s
Attitude Control (BCT)
<75 arcsec 3σ pointing
Reaction Wheels, IMU
Sun Sensors, Star Tracker
UHF Loop Antenna (JPL)
- >0dB gain @ 30deg off-axis
- < 16mm stowed

MarCo Planetary Protection Strategy

- Demonstrate no significant impact to InSight bioburden allocation from MarCO propellant
  - Evaluate worst case plume exposure
  - Perform bioassays of propulsion units
- Demonstrate compliance via bioburden for potential Mars impacts
  - Conservative bioburden estimation for remainder of flight modules to assess spore burden at launch
  - Assess worst-case vehicle breakup and burnup analyses to estimate heating and maximum surviving bioburden at impact

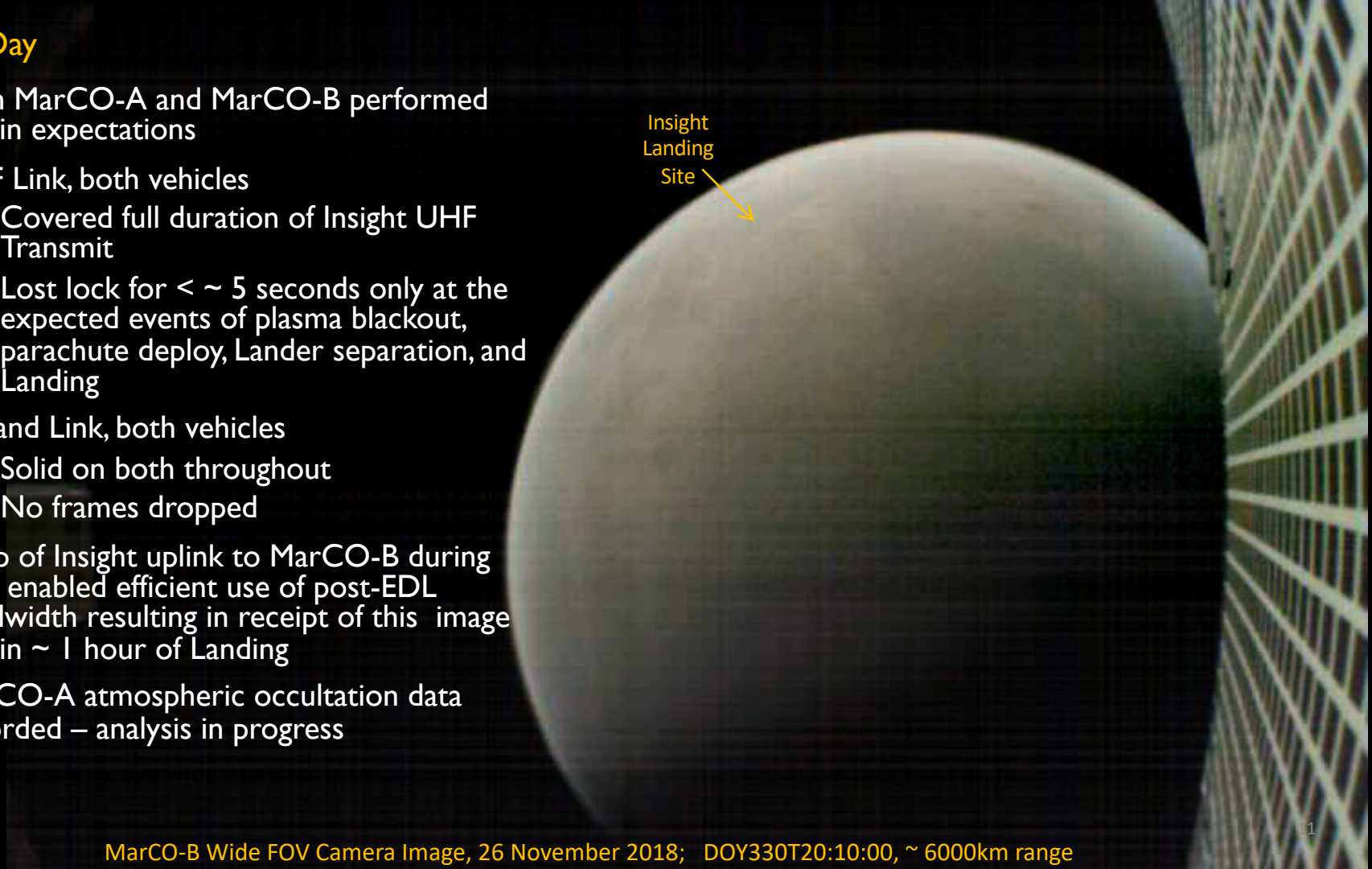



CURIOSITY ACE
OPPORTUNITY ACE
MarCO - A
MarCO - B


APPROACH
DSN TRACKS:
DOY327
DOY328
DOY329
Mon 26 Nov
DOY330
Tues 27 Nov
DOY331
Wed 27 Nov
DOY332
DSS-34 (MSPA)
DSS-54
DSS-25 (MSPA)
DSS-35 (MSPA)
DSS-55
DSS-14 (MSPA)
DSS-36 (MSPA)
DSS-55
DSS-24 (MSPA)
DSS-36 (MSPA)
DSS-63
DSS-65
DSS-24
54 Up
LANDING DAY
BOT 14:05 UTC
15:30 UTC
16:00 UTC
~20:10 UTC
EOT 22:55 UTC
DSS-54:
UP: B
DSS-63:
UP: B
UP: A
DOWN: A & B
MarCO-A:
15:52 SCET
16:00 ERT
19:05 SCET
19:27 SCET
19:57 SCET
20:40 SCET
21:28 SCET
21:33 SCET
22:45 SCET
A: Occultation
Recharge
Tx/Rx 1 Hr
Recharge
Tx/Rx
EDL Bent Pipe Relay
30 min
TxRx ReXmit Insight Data x2
Image & Recharge
Carrier 10 min
Recharge
13:58 SCET
14:05 ERT
14:58 SCET
15:05 ERT
Phobos
IRIS Remains Powered
20:17 SCET
20:58 SCET
21:43 SCET
21:51 ERT
Recharge
Tx/Rx 1 Hr
Recharge & Mars Image
Tx
Image Mars
TxRx ReXmit Insight Data x2
Mars & Deimos Image
TxRx 65 min
Recharge
MarCO-B:
LOS
(A)
Retransmit Insight Data
(A) 20:40 SCET
20:48 ERT
EDL RELAY
MarCO A/B:
Downlink Recorded Data
Bent Pipe Mode
(B) Image Mars
(B) Retransmit Insight Data
(B) 20:55 SCET
21:03 ERT
AOS
19:05 SCET
19:13 ERT
* Start Turn to EDL Attitude
19:23 SCET
19:31 ERT
* (B)Start turn to Phobos & Image
19:08 SCET
19:16 ERT
*Expect 1-2 minute Loss of Signal (LOS) during slew
Enter Bent Pipe Mode
19:27 SCET
19:35 ERT
UHF Carrier
19:33 SCET
19:41 ERT
UHF Telemetry
19:38 SCET
19:46 ERT
Chute
~ 19:43 SCET
~ 19:51 ERT
Lander Sep
~ 19:45 SCET
~ 19:53 ERT
Touch Down
~ 19:46 SCET
~ 19:54 ERT
UHF OFF
19:51 SCET
19:59 ERT
End Bent Pipe
19:57 SCET
20:05 ERT
Start turn To Image: LOS
20:04 SCET
20:12 ERT
Complete Turn To ReXmit: AOS
20:14 SCET
20:22 ERT
Finish ReXmit #1
20:40 SCET
20:48 ERT
Finish ReXmit #2 & LOS
Insight Events

EDL Day

- Both MarCO-A and MarCO-B performed within expectations
- UHF Link, both vehicles
  - Covered full duration of Insight UHF Transmit
  - Lost lock for < ~ 5 seconds only at the expected events of plasma blackout, parachute deploy, Lander separation, and Landing
- X-Band Link, both vehicles
  - Solid on both throughout
  - No frames dropped
- Swap of Insight uplink to MarCO-B during EDL enabled efficient use of post-EDL bandwidth resulting in receipt of this image within ~ 1 hour of Landing
- MarCO-A atmospheric occultation data recorded – analysis in progress



MarCO-B Wide FOV Camera Image, 26 November 2018; DOY330T20:10:00, ~ 6000km range

Toward Scientific Applications

- Communications can be decoupled from primary assets during critical events
- Small, focused, spacecraft can provide unique value
- Operations have significant challenges, and multiple assets can multiply challenges

Concluding…

- SmallSats are viable in the interplanetary arena
- Opportunities abound to add scientific value (e.g., Phobos / Deimos / Occultation)

Dare Mighty Things

Jet Propulsion Laboratory
California Institute of Technology